Effect of Pruning on the Growth and Development of *Protea* 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.)

By

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature

Date

Summary

The main purpose of producing cut flowers is to earn a satisfactory income with the first endeavour normally to increase the total number of flowers produced. This has limits due to the number of flowers that can be produced per plant or per area planted. Another method is to get the bulk of the crop in the longest possible stem length category to earn better prices. A third option is to target the seasons or times of the year when prices are naturally higher due to a positive ratio between demands and supply. Most of the protea cultivars grown commercially in South Africa flower outside the period September to January when prices and demand for proteas on the European markets are high. Previous work established that the flowering period of some protea cultivars could be modified to more favourable marketing periods through the timing of the pruning operation.

Plants of *Protea* 'Pink Ice' were pruned at monthly intervals from January to December 1999. For the first crop after pruning the highest yield was achieved for plants pruned in June. Flowers borne on an autumn flush needed 4 to 6 weeks longer to complete their development than for spring flush borne flowers. However, since flower initiation in autumn occurred earlier by more than 3 months than on the spring flush, this difference in time accounted for the earlier flowering of the former in spite of a longer period to complete the flower developmental process.

The effect of cropping this cultivar in a biennial system was tested against actual prices to test the validity of the finding that the June treatment resulted in the highest number of harvestable stems. It was found that the June treatment also gave the best income and the phasing of production resulting from a June pruning in a biennial cropping system fitted this cultivar the best. Orchards should be divided in two blocks with one in the 'on year' and one in the 'off year'.

The length of the shoot stub left after a shoot has been pruned determines the nature of the regrowth. Four-year-old plants of *Protea* 'Pink Ice' were pruned to four different bearer lengths in November 1999 or February 2000. Plants were pruned that either a half, one, two or three flush length bearers were left on the plants. Plants with the two longer categories of bearers took the shortest time to sprout buds from axillary

positions on the bearers and also had the most buds developing into shoots. The longer bearers produced more flowers per plant but the average length of the flowers was shorter than the plants with shorter bearers. The average total income was more in the instance of the longer bearers due to more flowers and the earlier harvest resulting from buds sprouting earlier.

Die effek van snoei op die groei en ontwikkeling van *Protea* 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.)

Opsomming

Die hoofdoel vir die produsering van snyblomme is om 'n bevredigende opbrengs te lewer en normaalweg word daar eerstens gepoog om soveel moontlik blomme in totaal te kweek, maar daar is beperkinge op die aantal stele wat per area of per plant geproduseer kan word. Nog 'n metode is om die langste moontlike stele te lewer uit die grootste gedeelte van die oes aangesien langer stele beter pryse realiseer. 'n Derde opsie is om die grootste deel van die oes te lewer gedurende die periodes wanneer die pryse die hoogste is as gevolg van 'n positiewe verband tussen vraag en aanbod. Die meeste van die Protea kultivars wat in Suid-Afrika gekweek word blom buite die periode van September tot Januarie wanneer vraag en dus pryse vir Proteas op die Europese markte hoog is. Vorige navorsingswerk het gevind dat die blomperiode van sommige Protea kultivars geskuif kan word na die beter bemarkingsperiodes deur die regulering van die snoeityd.

Plante van *Protea* 'Pink Ice' is op 'n maandelikse basis gesnoei vanaf Januarie tot Desember 1999. Die plante wat in Junie gesnoei was, het met die eerste oes die meeste stele gelewer. Blomme wat aangelê is op 'n Herfs groeistuwing het tussen vier en ses weke meer tyd nodig gehad om oesryp te raak as die blomme wat op 'n Lente groeistuwing ontwikkel het. Die blominisiëring op die Herfs groeistuwing het egter ongeveer drie maande voor die op die Lente groeistuwing begin en hierdie verskil in tyd het die vroeër blom verklaar ten spyte van die langer ontwikkelingstyd.

Die effek van 'n tweejaarlikse oessisteem vir die kultivar is getoets aan werklike markpryse om te bepaal of die Junie snoeidatum, wat die meeste stele opgelewer het, ook finansieël die beste gaan presteer. Daar is gevind dat die Junie behandeling ook die beste opbrengs opgelewer het. Boorde behoort verdeel te word in twee blokke met een deel in die produksiejaar en die ander deel in die groeijaar.

Die lengte van die stompie wat gelaat word nadat die loot gesnoei is, bepaal die aard van die hergroei. Vierjaar-oue plante van *Protea* ‘Pink Ice’ is gesnoei na vier verskillende draerlengtes in November 1999 of Februarie 2000. Plante is gesnoei sodat daar draers van ‘n halwe, een, twee of drie groeistuwings op die plante gelaat is. Plante met die langer draers het die kortste tyd geneem voordat knoppe in die blaaroksels begin groei het en hulle het ook die meeste aantal knoppe gehad wat begin groei het. Die langer draers het ook die meeste aantal blomme per plant geproduseer, maar die gemiddelde steellengte van die blomme was korter as dié wat geoes is van plante met korter draers. Die gemiddelde totale inkomste per plant was die hoogste in die geval van die plante met die langer draers, as gevolg van die groter aantal stele asook ‘n vroeër oes wat gerealiseer het, omdat die knoppe vroeër begin groei het uit die blaaroksels.

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Soli Deo Gloria

CONTENTS

Introduction

Plants from the Proteaceae family and specifically the genus *Protea* have been grown in South Africa in commercial orchards since the early 1960's. The main purpose was to improve the quality of the flowers compared to those that were harvested from the natural growing areas, where it was not feasible to treat the plants with chemicals against pests and disease or to fertilise and prune the plants to produce blemish free stems of more than 60 cm length on a consistent basis. As the consumer got used to better quality, they preferred not to buy flowers that were harvested from the natural areas as quality and vase life could not be assured.

At first the orchards were grown from seed and the plants reacted as a natural stand in the manner and time of flower production. Natural variation in flower colour and shape was also prevalent. It was found that through the establishment of clonal orchards the specific traits of the parent plants could be utilised in commercial orchards to the economic benefit of the producer. The next question was whether these commercial orchards could be forced to flower in economically better periods when demand was high and supply low. Research work established, for example, that the flowering time of *Leucospermum* could be delayed to periods of better returns through the disbudding technique (Gerber *et al*., 2001a).

For a producer it is imperative that the flowers are produced during periods of high demand as prices are up to three times more three to four months earlier or later than the normal flowering period. Much work has been done over many years to determine the factors affecting flower initiation in *Protea*, but to a large extent these factors are still unclear. In the genus *Protea*, unlike the genus *Leucospermum*, the time of flowering varies greatly not only within the genus, but also intraspecifically. Success in the shifting of flowering time was achieved with the timing of pruning in some cultivars such as 'Carnival' (*P. neriifolia* x *P. compacta*) (Gerber *et al*., 1995). The question was if this could be achieved with 'Pink Ice' (*P. compacta* x *P. susannae*) as well, one of the important commercial cultivars in South Africa covering about 7% of the planted area (SAPPEX, pers. comm.). The purpose of this study was therefore to determine the effect of pruning plants of 'Pink Ice' on the flower yield, quality and flowering time.

Literature Review: The flowering process in *Protea*

Introduction

The genus *Protea* consists of roughly 1,400 species of which approximately 400 occur in SA (Rebelo, 2001). Many of the species, such as *Protea repens, P. magnifica, P. eximia, P. cynaroides* and *P. compacta* have commercial value as cut flowers. Better prices are obtained for proteas on the European markets during the period September to end of January. Europe is by far the most important destination for South African produced proteas with this market accounting for about 90% of exported proteas (SAPPEX, Pers. Comm.). *Protea* species with commercial value flowering during this period are limited to *P. magnifica, P. grandiceps, P. cynaroides* (certain ecotypes) and *P. eximia*. Most of the interspecific hybrids of protea, for example 'Lady Di' (May – July) and 'Pink Ice' (February – May) flower outside this desired window of September to January.

Time of flower initiation

Shoot extension growth in proteas occurs in distinct growth flushes. The number of shoot growth flushes is species and cultivar dependent. The cultivars 'Sylvia', 'Cardinal' and 'Carnival' produce up to four growth flushes a year. These were designated as spring, 1st and 2nd summer and autumn flushes by Gerber *et al*., (2001a). *P. magnifica* on the other hand has no more than two flushes per year. Young vigorous plants produce more shoot growth flushes per year than older more complex plants. In controlled conditions it was found that that the number of growth flushes required for flower initiation decreases as the order of the axis increased (Allemand *et al*., 1995; Allemand *et al*., 1997).

Gerber *et al*. (2001a) have shown that in 'Sylvia', 'Lady Di' and 'Carnival' during extension growth of a flush, leaf primordia of the succeeding flush are differentiated, with the result that at completion of a growth flush the terminal bud contains a preformed shoot of the next flush. Differentiation of involucral bract primordia occurs during extension growth of the shoot growth flush subtending an inflorescence (Gerber *et al*., 2001a). Since the phyllotaxis of involucral bracts differs from that of leaves, Gerber *et al*. (2001a) concluded that flower initiation occurs at the time of onset of a shoot growth flush that subtends an inflorescence.

In 'Sylvia' and 'Lady Di' flower initiation occurs predominantly on the spring flush situated terminally on over-wintering shoots (Gerber *et al*., 2001a). This strategy of flower initiation apparently applies also to *P. magnifica, P. grandiceps, P. neriifolia, P. cynaroides* and the cultivars 'Susara', 'Sheila' and 'Pink Velvet'.

In the case of 'Sylvia' flower initiation can occur on any of the flushes, however the propensity to initiate flowers is greater on a spring flush that develops terminally on an over wintering shoot than on the 1^{st} and 2^{nd} summer and autumn flushes. This also applies to 'Cardinal'. The ability of 'Sylvia' and 'Cardinal' to initiate flowers on any flush is possibly carried over from one of their parents (*P. eximia*), which has a characteristic to initiate flowers on any one of the terminal flushes. However, in contrast to 'Sylvia' and 'Cardinal' the propensity to initiate flowers is greater in shoot growth flushes that occur during late summer and autumn for *P. eximia*. This would explain why *P. eximia* flowers predominantly from July to November, as compared to February to March for 'Sylvia' and 'Cardinal' (Hettasch, 1999).

Plasticity in bearing habit

The tendency to initiate flowers is greater on long, thick, terminal, over-wintering shoots for species and cultivars that initiate flowers predominantly on the spring growth flush (de Swardt, 1989; Greenfield *et al*., 1994; Gerber *et al*., 1995). Although not quantified, it is clear from field observations, that thin, over-wintering shoots, irrespective of length, rarely flower, whereas thick shoots, even if short, initiate flowers. It is also clear from field observations that for cultivars such as 'Sylvia' and 'Carnival' which initiate flowers on any growth flush, that for this to occur on the 1^{st}, 2^{nd} and autumn flushes, longer and thicker shoots are required, than for over-wintering shoots which flower on the spring flush.

In 'Carnival', a shoot growth flush originating from an axillary position can initiate a flower, but this only occurred on a spring flush of a vigorous over-wintering shoot. After completion of extension growth of the spring flush, flowers initiate on shoots sprouting from axillary buds below the developing inflorescence (Gerber, unpublished data). These shoots are comparable to 1^{st} summer shoots. On rare occasions flower initiation occurs on the autumn flush of 'Carnival' (Greenfield *et al*., 1994).

'Carnival' plants pruned back to bearers in March and April cause axillary buds to sprout before winter. Spring flushes that developed terminally on the pre-winter formed shoots, initiate flowers (Greenfield *et al*., 1994). In addition, shoots failing to initiate flowers on the spring flush do so on the 1^{st} summer flush. Flowers rarely form on the 2^{nd} summer flush. However, when plants are pruned in June to August, spring flush shoots originating from an axillary bud rarely initiate a flower (Greenfield *et al*., 1994).

In cultivars such as 'Carnival' there is, therefore, some degree of plasticity in their bearing habit. Flower initiation occurs predominantly on spring flushes, borne terminally on over-wintering shoots. Flower initiation can also occur on shoots that develop from axillary buds below a developing inflorescence on a spring flush, as well as on 1^{st} summer flush growth where plants were pruned in March to May. Flower initiation rarely occurs in 2^{nd} summer or autumn flushes.

Flower induction

Environmental and intra-plant conditions favouring flower initiation are poorly understood in proteas. Gerber *et al*. (2001b) defoliated four-flush shoots of 'Carnival' in winter. Completely defoliating shoots more than 6 weeks before bud break prevented flower initiation on the subsequent spring flush. Defoliation closer to bud break in spring did not affect flower initiation. They concluded that leaves are essential for shoots to become induced to flower. Furthermore, the leaves should be present at least 6 weeks prior to bud sprouting in spring. This implies that 'Carnival' shoots are induced to flower 6 weeks before flower initiation occurs on the spring flush. Whether induction of shoots to initiate flowers is caused by environmental factors such as low temperatures or short days during winter is unknown. It is also possible that induction could entirely be dependent on intra-plant factors such as root-produced cytokinins during the autumn resumption of root growth.

The duration of the induced state is unknown but general conclusions can be drawn from the plasticity in flower initiation. The spring growth flush is completed during

October. Since axillary shoots develop below an inflorescence on a spring flush, or on the 1st summer flush (after specific pruning) it is indicative that the induced state lasts up to the time when the spring flush is completed. In South Africa, bud sprouting in spring for 'Carnival' occurs during the last week of August (Gerber *et al*., 1995). Temperatures are still low and days are relatively short which could be inductive for flower initiation and/or root-produced cytokinins from increased root growth could cause induction. The fact that flowers do not develop on the 2nd summer flush means that the induced state for flowering dissipated (Gerber *et al*., 1995).

In summary, conditions inductive for ‘Carnival’ appear to be:
(1) Over-wintering shoots with minimum but unspecified dimensions in terms of thickness and length.
(2) Shoots should have an adequate carbohydrate status with a specific photosynthetic capacity.
(3) Factors associated with winter conditions which are determined by either environmental or intra-plant conditions or a combination of these.

Flower Development

As stated earlier, differentiation of the involucral bracts is completed at the time when the extension growth of the flush subtending the inflorescence is completed (Gerber *et al*., 2001c). Subsequently floral bracts and florets in the axils of the floret bracts differentiate. The number of florets per flower is species or cultivar dependant (Rebelo, 2001). As the inflorescence increases in size, the florets differentiate and enlarge until anthesis. The rate of flower development is source dependant. Flowers borne on long thick shoots have a shorter developmental period until anthesis than flowers borne on thinner and shorter shoots (Pers. obs.). Defoliation of the over-wintering shoots extends the developmental period of the flower in ‘Carnival’ (Gerber *et al*., 1995). Defoliation of both the over-wintering shoot and the spring flush cause flower abortion or arrests the further development of the inflorescence in ‘Lady Di’ (Gerber *et al*., 2001b).

Environmental factors, of which temperature is possibly the most apparent, mainly affect the rate of flower development. This is particularly evident in the cultivars that initiate an inflorescence on any of the shoot growth flushes. For 'Sylvia' the developmental period for inflorescences with a basal diameter of 10 mm until anthesis, varies from three months for inflorescences borne on the spring flush to six months for inflorescences borne on the autumn flush (Gerber *et al.*, 2001c).

Manipulation of flowering time

Up to now two approaches have been successful in manipulating the flowering time of proteas. In the case of 'Carnival', two principles are exploited to achieve earlier flowering. Firstly, it is known that by pruning 'Carnival' plants to bearers in July-August prevents flowering on the subsequent spring and 1st summer flushes (Hettasch *et al*., 1997). The shoot elongates by the formation of successive growth flushes. At the onset of the following winter, four-flush-shoots are predominantly present on the plant. The second principle exploited is that inflorescences, developing on long thick shoots, have a shorter developmental period to anthesis than inflorescences developing on shorter, thinner shoots. Four-flush-over-wintering shoots initiate inflorescences on the spring flush, which develop terminally on the over-wintering shoot yielding a five-flush-shoot. Flowers borne on these shoots flower 2 months sooner than flowers on two-flush-shoots. Sixty percent of the five-flush-shoots are picked in February as compared to 4 percent of the two-flush-shoots (Hettasch *et al*., 1997).

This procedure implies that a flower crop is harvested only every 2nd year. The first year is utilised to produce four-flush-shoots and the second year a spring flush and flower. Growers therefore need two blocks, one in the 'off-year' and another in the 'on-year' to continuously produce flowers. High yields of flowers with longer stems that flower earlier outweigh the negatives of a crop every second year (Hettasch *et al*., 1997).

In the case of 'Sylvia', when plants are pruned to bearers in July-August, the subsequent spring flush or 1st summer flush does not initiate flowers. Dry mass and carbohydrate (starch and sugars) build up in shoots, lag shoot extension growth (Hettasch, 1999). This is particularly the case with the spring and 1st summer flushes. The lag in carbohydrate accumulation is greatly reduced in the 2nd summer and autumn flushes due to the rapid increase in the photosynthetic source due to the functional leaves of the first two or three flushes. Since 'Sylvia' can initiate an inflorescence on any flush, the shoot characteristic by May following pruning is conducive for flower initiation on the autumn flush. These flowers reach harvesting stage during September to December, which is in a better price period than flowering in January to March, which occurs when flowers initiate on a spring flush (Gerber *et al*., 2001c).

Conclusion

Although work has been done addressing various aspects of flower initiation in protea, no single controlling factor could be pinpointed that could help in determining inductive factors. Within the genus *Protea* flowering varies greatly, indicating that a single process would most probably not explain the flowering stimuli in all species. The identification and investigation of various triggers in the flower initiation process of protea continues in the work done on cultivar level, as the intra-specific variation in this genus precludes conclusions to be drawn from work done on species level.

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Paper 1-: Time of pruning affects the yield, flowering time and flower quality of *Protea* cv. Pink Ice (*P. compacta* R. Br. x *P. susannae* Phill.)

Abstract

Plants of 'Pink Ice' were pruned at monthly intervals from January to December 1999. Single plants were used per treatment and treatments were repeated five times in a randomised complete block design. For the first crop after pruning the highest yield was achieved for plants pruned in June. However, more flowers were harvested during the high price period of December and January when plants were pruned in March. Except when pruning was done in December, January or February, the yield of the return bloom was *ca*. 50 percent of the first crop with few shoots flowering during December or January. High yields were achieved in the return bloom for plants pruned in December, January or February, but only the latter two dates of pruning produced shoots that flowered during December or January. About 40 percent of the shoots that were 70 cm or longer by the month of May preceding the first flowering period had initiated flowers. Flowers borne on an autumn flush needed 4 to 6 weeks longer to complete their development than for spring flush borne flowers. However since flower initiation in autumn occurred earlier by more than 3 months than on the spring flush, this difference in time accounted for the earlier flowering of the former in spite of a longer period to complete the flower developmental process.

Introduction

Most of the protea cultivars grown commercially in South Africa e.g. 'Pink Ice', 'Carnival', 'Brenda' and 'Susara' flower outside the period September to January when prices and demand for proteas on the European markets is high. A number of protea species do flower during the desired window such as *P. magnifica, P. grandiceps,* and certain ecotypes of *P. cynaroides* as well as *P. eximia*. Hybrids of the latter species with other protea species such as *P. compacta* and *P. neriifolia*, however, flower earlier than September, which limits their commercial value. Greenfield *et al*. (1994) and Gerber *et al*. (2001a) were the first to attempt shifting the flowering time of proteas. They observed that 'Carnival', a natural hybrid between *P.*

neriifolia and *P. compacta*, initiate flowers almost exclusively on the spring flush and that flowers were harvest mature during March to May. However flowers initiate rarely when the spring flush originates from an axillary bud on a bearer after pruning plants in winter (Greenfield *et al*., 1994; Gerber *et al*., 1995). After pruning shoots grew in successive flushes and flowers only initiate on the next spring flush (Gerber *et al*., 2001b). This implies that when plants are pruned in winter the flower crop of the following autumn is sacrificed. Pruning in winter results in flowers being borne on long stems and time of flowering is advanced by 4 to 6 weeks. Apparently the advancement in the flowering time of 'Carnival' is due to an increase in the size of the photosynthetic source. Although a flower crop is realized only every second year the higher yields with flowering shoots of superior length result in higher income per plant (Gerber *et al*., 1995).

Protea eximia has the ability to flower on any flush and this characteristic is carried over to hybrids with *P. susannae* such as 'Sylvia' and 'Cardinal'. The research of Gerber *et al*. (2001a) revealed that the propensity to initiate flowers in 'Sylvia,' is greater for the spring flush, which will then yield harvestable flowers during January to March. Longer shoots are required to initiate shoots on other flushes. By pruning 'Sylvia' plants at different times of the year, Gerber *et al*. (2001a) have shown that the shoot growth could be synchronised and flower initiation effected on the second summer or autumn flush that will reach harvest maturity during September to December. Reasons for the requirement of a better quality shoot to initiate flowers on flushes other than the spring flush are poorly understood.

The purpose of this study was to determine whether pruning date of 'Pink Ice', a natural hybrid between *P. compacta* R. Br. and *P. susannae* Phill., can result in initiation of flowers during autumn and thus induce flowering during December and January.

Materials and Methods

Plant material and study site:

Three-year-old plants of 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.) growing in a commercial plantation about 40 kilometres south of Port Elizabeth, Eastern Cape, South Africa (lat. 33°30'S: long. 24°55'E, altitude 240 m), were used in the trial. The area is in the transition zone between the winter and summer rainfall areas, and has an average annual rainfall of 700 mm. The climate is mild with the orchards about 5 km from the Indian Ocean. The 30-year maximum and minimum average daily temperatures for Port Elizabeth, which is about 30km to the east, are 24°C and 21°C during summer and 21°C and 11°C during winter (South African Weather Services).

The orchards are irrigated by drip irrigation with irrigation needs determined by tensiometer readings. The soils are sandy loams underlain with thixotropic sub-layers. The plants were planted on raised beds of about 30 to 40 cm high by one meter wide to overcome the problems associated with these thixotrophic layers. Normal cultivation practices of the commercial orchards such as pest, disease and weed control, and fertilisation, were followed in the trial plot. Plants were grown in rows 3 meters apart with 1 meter between plants in the row (3,300 plants per hectare) and it received the normal practice of pruning during and after harvesting in preceding years. The orchard had already produced a harvest in the previous year and the shoots pruned in this trial were shoots that grew from axillary buds on stems that were harvested from January to May 1998.

Trial layout and design:

The trial was laid out in a row in the commercial orchard and plants randomly allocated to the pruning dates. Five plants were pruned approximately four weeks apart on the following dates in 1999: 14 January, 16 February, 16 March, 16 April, 19 May, 18 June, 19 July, 19 August, 17 September, 20 October, 18 November and 28 December. The stems were pruned according to commercial practice by heading back both flowering and non-flowering shoots to the first intercalation, which left bearers of ±15cm in length with about 16 to 20 leaves per bearer.

Data recorded and statistical analysis:

The size of the plants was determined through the measurement of the diameter of the main stem at ground level and the number of bearers. Flowers were harvested through a heading cut at the first intercalation. Most shoots not flowering during this first harvest produced a flower during the following season and these flowers are classified as return blooms. During the harvesting operations, number of flowering stems, the length of each stem as well as the number of growth flushes per stem was determined. The average price per stem received on the farm for the different length classes was also recorded at the time of harvest.

Single plants were used per treatment, replicated 5 times in a randomised complete block design. Data were analysed by analysis of variance using the SAS General Linear Model (SAS, 2000).

Results

Irrespective of month of pruning, flowering rarely occurred from June to November and is thus limited between December and May (Table 1). For the duration of the trial 2,730 flowers were harvested of which only 111 (4%) flowers were picked from June to November (2000 and 2001) and for his reason these flowers were excluded from all other data presentations.

Monitoring the growth of a single shoot on each of two bearers per plant revealed that flower initiation occurred on either an autumn or spring flush. The increase in length and diameter of flowers on either an autumn or spring flush is presented in Figure 1. Flowers that initiated on an autumn flush reached anthesis earlier (16 December vs. 9 March) despite a longer growth period than flowers borne on a spring flush. From the stage that flowers were *ca*. 20 mm in diameter until anthesis required 14 weeks for flowers borne on an autumn flush compared to 10 weeks for flowers initiated on a spring flush (Figure 1).

Shoot length at harvest was positively correlated with shoot length in May (Figure 2). Short shoots in May resulted in short shoots at harvest. Flowers that were harvested early in the flowering season during December 2000 and January 2001 occurred predominantly on long shoots whereas shorter shoots flowered later during February

2001 to May 2001. An overlap in shoots of intermediate lengths and time of flowering was evident (Figure 2). The increase in shoot length from May 2000 to harvest was greater for shoots that were short in May 2000 than for long shoots (Figure 3). The length of short shoots in May 2000 increased by ± 40 cm whereas long shoots increased by ± 20 cm before flowering.

For plants pruned in January or February 1999 the trial extended over three harvest seasons (March – May 2000, December 2000 – May 2001 and December 2001 – May 2002) whereas for the other pruning dates only the latter two harvest seasons were experienced (Table 1). During the period December 2000 to May 2001 more flowers were picked from plants pruned during June or July (37), compared to pruning earlier or later in 1999 (Table 1). The return bloom during December 2001 to May 2002 was less than half of the yield of the previous year, 12 and 14 respectively. Only in the case of plants pruned in December 1999 were more flowers picked in December 2001 to May 2002 compared to the previous year (Table 1). The month of pruning had a profound effect on the proportion of the crop that is harvested during December 2000 and January 2001 compared to February to May 2001 (Table 2). Only when pruning was done in January or February 1999 did flowering occur during autumn 2000. Approximately 50% of the flowers from plants pruned between January and March 1999 were picked during December 2000 and January 2001 evaluated against the period February to May 2001. This percentage decreased rapidly with later pruning dates and less than 10% were achieved for plants pruned in September 1999 or later in that year (Table 2). During the time window of February to May 2001 more flowers were harvested from plants pruned July or August than from plants pruned earlier or later. The return bloom of December 2001 to January 2002 yielded only a few flowers with the bulk of the crop picked during February to May 2002 (Table 2).

In Table 3 the data was rearranged to reflect a series of increasing time between pruning and the month of May that either preceded the first cropping season thereafter, or the return bloom of the next cropping season. The data reveal that the shortest period from pruning to May viz. 73 days that yielded over-wintering shoots that initiated flowers on the subsequent spring flush, were achieved for plants pruned in February 1999 where 6 shoots per plant initiated flowers on the spring flush of 1999 (Table 3). Plants that were pruned in July or June, 317 and 286 days before May 2001 (respectively), yielded the most shoots that initiated flowers on either the autumn flush or spring flush of 2001. The yield decreased with earlier pruning from May to March 1999. The yield was also suppressed for plants pruned in October and to a lesser extent for those pruned in September. The highest number of flowering shoots produced in the following season (December 2001 to May 2002) was from those treatments (pruned in December, January or February of 1999), which gave the lowest yield the previous season. The combined yield of the two flowering seasons was the highest when pruning was done in July (50) and the lowest yield resulted if pruning was done in October (33) followed by February (35) and March (36) pruning. When the period from pruning to May was less than 255 days, few stems were harvested during December and January of the first flowering period after pruning (Table 3). With increasing number of days between pruning and May the number of flowers harvested per plant during December and January increased to 14 flowers harvested per plant when 411 days separated the date of pruning in March 1999 and May 2001. For the return crop only plants pruned in January or February 1999, 472 and 439 days before May 2000 respectively produced high numbers of shoots that flowered during December or January. For the other pruning dates irrespective of the number of days between pruning and May 2001 that extended from 489 to 776 days, few shoots were produced per plant that flowered between December and January.

The flowering pattern of the December 2000 to May 2001 crop clearly displays two phases (Figure 4). An early flowering period of short duration that occurred during December 2000 and January 2001, followed by a protracted flowering period that lasted from February 2001and ended in May 2001.

The relationship between stem length and harvest date is presented in Figure 5. For the harvest season of December 2000 to May 2001 it shows that flowers picked in December had stems longer than 120 cm. As the harvest season progressed average length of shoots harvested decreased and by April were only half as long as in the beginning of the picking season. A comparable decrease in shoot length with a progression of the harvesting season is revealed for the other two seasons presented in Figure 5.

Discussion

According to Gerber *et al*. (2001a) 'Sylvia' initiates flowers at any time of the year and year round flowering is thus possible. In the case of 'Carnival', flower initiation is essentially limited to the spring flush that develops terminally on over-wintering shoots (Gerber *et al*., 2001b). The time of flowering is thus limited to between February and May (Gerber *et al*., 1995). Early flowers (February - March) are borne on long thick shoots and it appears that the size of the photosynthetic source determines the time of flowering within the window of February to May (Greenfield *et al*., 1994; Gerber *et al*., 1995).

'Pink Ice' rarely flowered between June and November irrespective of pruning date (Table 1). Unlike 'Sylvia' (Gerber *et al*., 2001a) that can initiate flowers on any one of the shoot growth flushes, flower initiation in 'Pink Ice' occurred on either an autumn or a spring shoot growth flush (Figure 1). Flower initiation in 'Pink Ice' is thus not limited to a spring flush that develops terminally on an on over-wintering shoot as is the case with 'Carnival (Gerber *et al*., 2001b). Had the latter been the case flowering would have been limited to between February and May as is the case with 'Carnival' (Greenfield et al., 1994; Gerber et al., 1995) but the flowering time extends from December to May (Table 1).

Although flowers on an autumn flush developed at a slower rate during winter and required 4 to 6 weeks more to reach anthesis (Figure 1), compared to flowers on a spring flush, the former flowered earlier (December and January), whereas flowering of spring flush flowers only started in February and extended to end of May. However 'Pink Ice' initiated flowers more readily on a spring flush that developed terminally than on a autumn flush as is evident by the more shoots flowering between February and May as compared to December to January (Table 2). The graphical representation of the flowers of 'Pink Ice' harvested weekly (Figure 4) also clearly displays two peaks of flowering representing flowers initiated on an autumn or spring flush, respectively. Apparently 'Pink Ice' is in terms of flower initiation comparable to 'Carnival' but initiates flowers more readily on an autumn flush than 'Carnival'.

In 'Sylvia', longer shoots consisting preferably of three flushes, are required for initiation to occur on an autumn flush as compared to an over-wintering shoot consisting of only one or two flushes that can lead to flower initiation on a spring flush (Gerber *et al.*, 2001a). The relationship between the shoot characteristics such as length in May and at harvest is useful to partially explain the flowering behaviour in 'Pink Ice'. It is clear from Figures 2 and 5 that it is predominantly the long shoots that initiated flowers on an autumn flush and reached picking maturity in December or January. The fact that long shoots in May had only extended by ±20 cm at harvest (Figure 3) is indicative that only one flush was added *viz*. an autumn flush. In contrast, short shoots in May extended by another ±40 cm at harvest, which equates to two flushes *viz*. an autumn and a spring flush. Since there is an overlap in shoot length and time of flowering it is clear that shoot length is not the only determining factor with regard to flower initiation. Gerber *et al*. (2002) have shown that leaves and therefore photosynthates are required to effect flower initiation in 'Carnival'. There is however large differences in the size of the photosynthetic source between one- and two-flush over-wintering shoots and a five- or six-flush shoot as a prerequisite for flower initiation. We concur with the conclusion of Gerber *et al*. (2002) that there are conditions present, either environmental or intra-plant, that favours flower initiation on a spring flush. Apparently a large photosynthetic source could to some degree compensate for this and effect flower initiation on an autumn flush in 'Pink Ice' but not in 'Carnival'.

The relationship between the time of pruning and the month of May is useful to explain the subsequent flowering behaviour as affected by pruning (Table 3). Pruning in January or February 1999, 106 and 73 days before May 1999, permitted development of shoots before winter that could, after over-wintering, initiate flowers on a spring flush of 1999 flowering from March to May 2000. Flowering occurred late because flowering shoots were relatively short, limiting the size of the photosynthetic source as described earlier for 'Carnival'. Average length in May 1999 for flowering shoots of autumn 2000 was 25.2 cm and 19.3 cm for the January and February pruned plants, respectively. For non-flowering shoots these lengths were 20.5 cm (January) and 13.7 cm (February), respectively. Pruning in March or April 1999 did not permit sufficient shoot growth before May 1999; therefore no flowers were produced on the spring flush of 1999 that originated from an axillary bud on the bearer. Flowers do not initiate on the spring flush that develops from an axillary bud on a bearer of either 'Carnival' (Greenfield *et al*., 1994; Gerber *et al*., 1995) or 'Sylvia' (Gerber *et al*., 2001a). The increase in the number of stems harvested between December 2000 and May 2001 for plants pruned, (with the exception of October), between December 1999 and June 2000 can thus be explained by the longer period from pruning to May 2000, permitting more shoots to have acquired the characteristic for initiation of flowers either on a autumn flush or a spring flush of 2000. The decrease in the number of harvested stems with even earlier pruning from May to March, and thus a further increase in the number of days to May, is apparently caused by fewer buds per bearer sprouting (See Paper 2).

The return bloom revealed the effect of unsynchronised shoot growth on the cropping pattern after pruning (Table 3). Irrespective of the pruning date, except for pruning in January or February, almost all flowers were picked in February to May 2002. This implies that shoots present on the plants at the end of May 2001 after the first crop had been harvested, failed to initiate a flower on an autumn flush but initiation occurred preferentially on the spring flush of 2001 and therefore flowering occurred only from February until end of May 2002. We advance the following explanations for the failure to initiate flowers on an autumn flush.

Firstly, after pruning the more distal buds on a bearer sprouted and grew more vigorously than shoots developing lower down on the bearer. Primegenic dominance of shoots that develop from buds that sprout a few days earlier over shoots that sprout from buds lower on a shoot is, according to Bangerth (1989), auxin related. Basipetally transported auxin, which is produced by the distal shoot, inhibits growth of shoots situated proximally on the bearer. Secondly, developing inflorescences on flowering shoots may compete strongly with non-flowering shoots for photosynthates, with the result that fewer shoot growth flushes occur on non-flowering shoots. Inhibition of shoot growth by developing reproductive structures such as fruit is well documented (Maggs, 1963). Thirdly, strong growth of the distally situated shoots on a bearer relative to shoots located lower down on the bearer may cause such shoots to be exposed to poorer light environment, both with respect to light intensity and light quality. Combined, these three factors were apparently responsible for shoots failing to initiate flowers on an autumn flush of the return bloom. To achieve a high proportion of shoots flowering during December and January proper synchronisation of shoot growth appears to be a prerequisite. To synchronise shoot growth it is also considered important that after pruning the number of shoots permitted to develop per bearer, be limited to only one or two depending on the number of bearers present on a plant.

However this explanation does not apply to the return bloom when plants were pruned in January or February. In this instance the first crop of flowers initiated only on a spring flush that developed terminally on short (±25 cm) over-wintering shoots. Shoots that did not initiate a flower continued to grow during spring of 1999 through to autumn of 2000. The short flower bearing shoots were thus subordinate to the non-flowering shoots, many which then succeeded to initiate a flower on an autumn flush of 2000 thus accounting for the high yields in the return bloom, of which a high percentage was harvested in December and January (Table 3). It is noteworthy that the second return bloom on plants pruned in January or February behaved in the same manner as the first return bloom on plants pruned from March to December (Table 2).

In conclusion, the strategy followed by 'Pink Ice' of initiating flowers on the spring flush is similar to 'Carnival'. However in contrast to 'Carnival', 'Pink Ice' has the ability to initiate flowers on an autumn flush provided shoot growth was synchronised by pruning preferentially in June (winter) and shoots have acquired a length of at least 70 to 80 cm by autumn.

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Table 1. Average number of stems harvested per plant during different time windows following pruning in 1999. Values rounded to the nearest integer.

		Number harvested per period				
Month of pruning in 1999	Total harvested Mar 2000- May 2002	Mar-May 2000	Jun - Nov 2000	**Dec 2000 - May 2001***	Jun - Nov 2001	Dec 2001 - May 2002
January	57	17	1	**23**	1	14
February	54	6	4	**29**	1	14
March	38	0	1	**30**	1	6
April	45	0	0	**32**	1	11
May	43	0	0	**34**	0	9
June	49	0	0	**37**	0	12
July	51	0	0	**37**	1	14
August	48	0	0	**35**	1	12
September	40	0	0	**28**	0	12
October	35	0	0	**20**	2	13
November[#]	41	0	0	**20**	2	10
December	46	0	0	**15**	5	26
Total	546					
Lin.[z]				*		
Quad.[z]				**		
Cub.[z]				**		

[#] November treatment has one missing value.

[z] *, ** significant at P=0.05 and P=0.01 respectively and n.s. is not significant according to the F-test

Table 2. Average number of stems or proportion of stems harvested per plant during December 2000 and January 2001 or February to May 2001 following pruning in 1999 of 'Pink Ice'. Values rounded to the nearest integer.

Month of pruning in 1999	Mar - May 2000	**Dec 2000-Jan 2001**	**Feb - May 2001**	% Of total harvested Dec 2000 - Jan 2001	Dec 2001-Jan 2002	Feb-May 2002	% Of total harvested Dec 2001 - Jan 2002
January	17	**11**	**12**	47%	1	13	7%
February	6	**14**	**15**	48%	1	13	7%
March		**14**	**17**	45%	0	5	0%
April		**12**	**21**	36%	0	11	0%
May		**8**	**25**	25%	1	8	11%
June		**9**	**27**	25%	0	12	0%
July		**7**	**30**	18%	1	13	7%
August		**5**	**30**	13%	1	11	9%
September		**0**	**27**	1%	2	9	18%
October		**1**	**19**	6%	2	11	15%
November*		**1**	**27**	3%	1	9	10%
December		**1**	**14**	8%	1	24	4%
Lin.^{z}		**	**n.s.**				
Quad.^{z}		**	**				
Cub.^{z}		**	**				

*November treatment has one missing value.

^{z} *, ** significant at P=0.05 and P=0.01 respectively and n.s. is not significant according to the F-test

Table 3. Relationship between the number of days from pruning in 1999 to the month of May and the flower yield in December of the same year plus the yield of January to May of the following year.

Month of pruning in 1999	Days from pruning to May 1999 or **May 2000**	Flower yield during Dec1999-May2000 or **Dec 2000 to May 2001**	Days from pruning to May 2000 or **May 2001**	Return bloom Dec2000-May 2001 or **Dec 2001-May 2002**	Combined yield
Feb	73	6 (0)[y]	439	29 (14)	35 (14)
Jan	106	17 (0)	472	23 (11)	40 (11)
Dec	**124**	**15 (1)**	**489**	**25 (1)**	**40 (2)**
Nov	**164**	**28 (1)**	**529**	**10 (1)**	**38 (2)**
Oct	**193**	**20 (1)**	**558**	**13 (2)**	**33 (3)**
Sep	**226**	**28 (0)**	**591**	**9 (2)**	**40 (2)**
Aug	**255**	**35 (5)**	**620**	**12 (1)**	**47 6)**
Jul	**286**	**37 (7)**	**651**	**14 (1)**	**50 (8)**
Jun	**317**	**37 (9)**	**682**	**10 (0)**	**47 (9)**
May	**347**	**34 (8)**	**712**	**9 (0)**	**42 (8)**
Apr	**380**	**32 (12)**	**745**	**11 (0)**	**43 (12)**
Mar	**411**	**30 (14)**	**776**	**6 (1)**	**36 (15)**

[y]( ) Number of flowers harvested per plant during December 2000 to January 2001 and December 2001 to January 2002 respectively

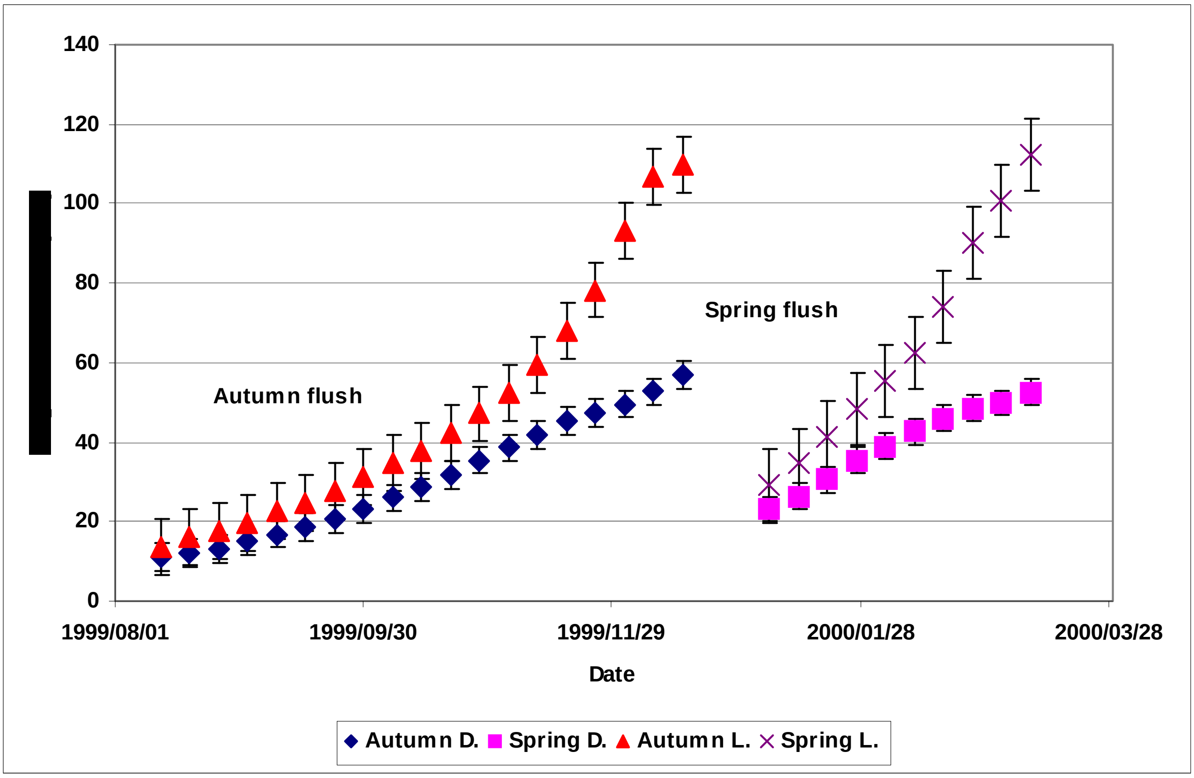

Figure 1. Growth rate of ‘Pink Ice’ inflorescences until anthesis over a period of 19 weeks in spring 1999 and 10 weeks in summer 2000 in length (L) and diameter (D) (average measurements of ten inflorescences measured from 12 August 1999 to 16 December 1999 on an autumn flush and 6 January to 9 March 2000 on a spring flush). Bars represent standard error.

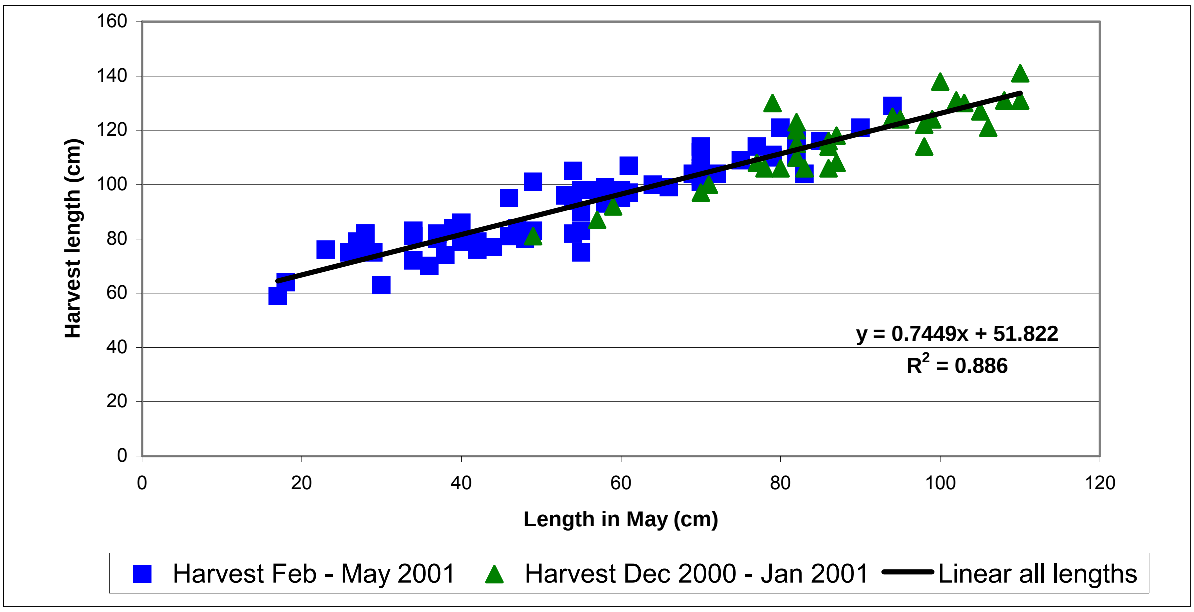

Figure 2. The relationship between the shoot lengths of ‘Pink Ice’ in May 2000 and at harvest.

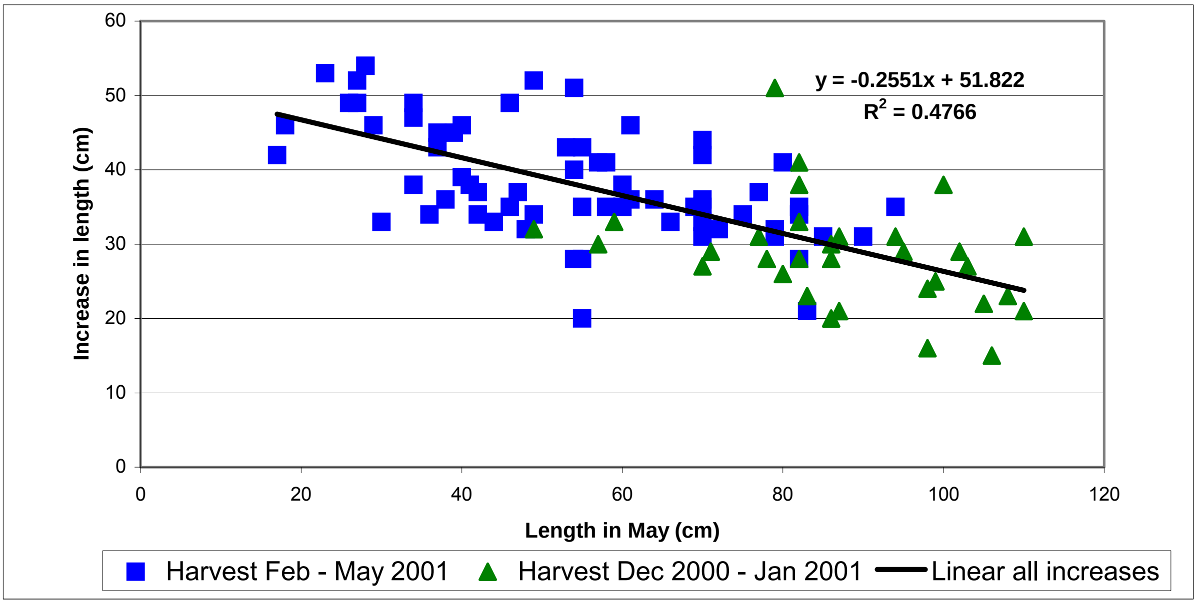

Figure 3. Increase in shoot length of ‘Pink Ice’ from May 2000 to harvest in December 2000 to January 2001 or February to May 2001.

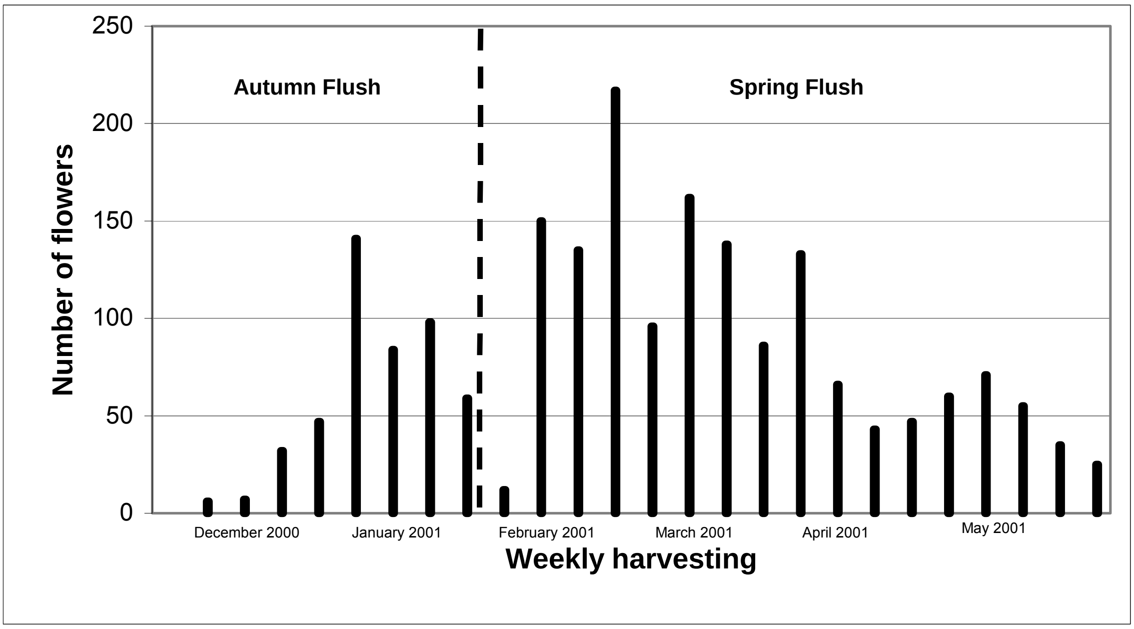

Figure 4. Cropping pattern of ‘Pink Ice’ for the December 2000 to May 2001 flowering season. Data shown are the total number of flowers harvested from all the months of pruning (January to December 1999).

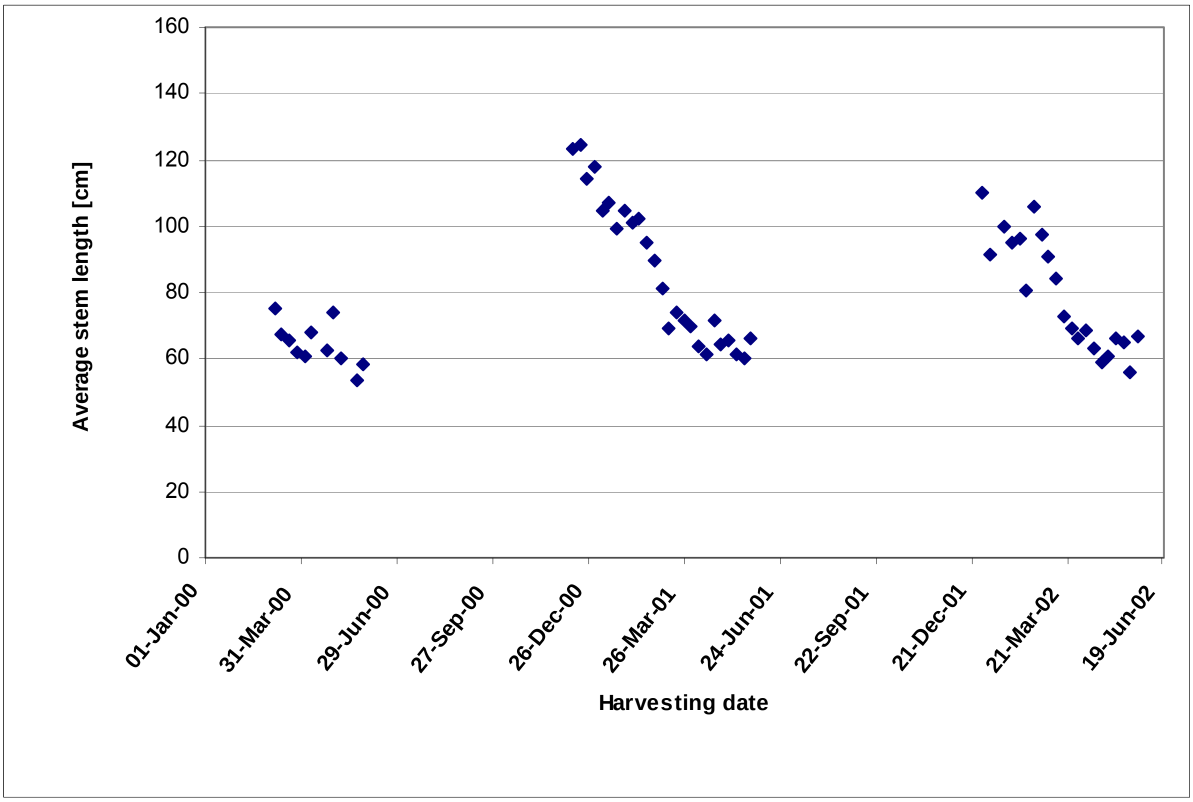

Figure 5. Mean stem length for weekly harvests of ‘Pink Ice’ for the period February 2000 to May 2002.

Paper-2 Effect of pruning plants to different bearer lengths in November or February on flowering of *Protea* cv. Pink Ice (*P. compacta* R. Br. x *P. susannae* Phill.)

Abstract

Four-year-old plants of *Protea* 'Pink Ice' were pruned to four different bearer lengths in November 1999 or February 2000. Plants were pruned that either a half, one, two or three flush length bearers were left on the plants. Single plants were used per treatment and treatments were repeated five times in a randomised complete block design. Leaving plants with only the short bearers (½ a flush length) in February resulted in all the plants as well as two of the plants with one flush bearers dying about two months after the treatment. The plants pruned in November leaving only short bearers showed stress signs with one dying. Plants with the two longer categories of bearers took the shortest time to have buds sprouting from axillary positions on the bearers (16 days for November treatment and 22 days for the February treatment) and also had the most buds developing into shoots (10 buds per bearer for November treatment and 11 and 8 for the February treatment). Over the two-year period that this trial was harvested the longer bearers produced more flowers per plant, but the average length of the flowers was shorter than for the plants with shorter bearers. The average total income was more for the longer bearers. More by-pass shoots had to be removed from flowering stems per plant from the longer bearers but the number per flowering stem was more for the plants with shorter bearers. The flowering period for the plants treated in November was to a large extent inside the normal peak period for 'Pink Ice' (February to May) for the first season of harvesting although some flowers were harvested later. The February treated plants with longer bearers' peak flowering was about three months later than normal and the one flush bearer plants' about five months later than the normal peak for this cultivar. The second harvest for all treatments was in line with the normal flowering period of this cultivar.

Introduction

Commercial cultivars from the *Proteaceae* are planted in increasing numbers in orchards in South Africa, as well as in some 10 other countries. The European market is still the prime destination for *Proteaceae* produced in South Africa, with about 90% of the production exported to Europe (Sappex, Pers. Comm.). The optimum time to export to Europe is during the European winter (September to February in South Africa) as flower production in the Northern Hemisphere is then lower than during the rest of the year. Previous work done on protea has established that the flowering time of some protea cultivars e.g. ‘Sylvia‘ can be shifted to the prime marketing window of September to February through the pruning of the plants at the appropriate time (Gerber *et al*., 2001b).

‘Pink Ice’ flowers naturally from February to May, however it is possible to achieve flowering during December and January by pruning the plants at the right time (Paper 1). It was however not possible to induce flowering during June to November by pruning (Paper 1). Flowering of ’Pink Ice’ during December and January resulted from shoots initiating flowers on an autumn flush of shoot growth (Paper 1). Flowering during December and January for the cultivar ‘Carnival’ was not achieved, irrespective of the month of pruning (Greenfield *et al*., 1994; Gerber *et al*., 1995).

The length of the shoot stub left after a shoot has been pruned determines the nature of the regrowth. In their book *‘Grondslagen van de fruitteelt’*, Tromp *et al*. (1976) presents data for apple trees that show that the total length of new growth increased the harder a shoot is headed back. However when more than 80% of a shoot is removed by pruning the length of new growth decreases. In this paper we report on the effect of pruning shoots of ‘Pink Ice’ and leaving bearers of different lengths on the nature of the regrowth and crop yield.

Materials and Methods

Plant material and study site:

In 1999, four-year-old plants of 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.) growing in a commercial plantation about 40 km from Port Elizabeth, Eastern Cape, South Africa (lat. 33°30'S: long. 24°55'E, altitude 240 m), were selected for this trial. The area is in the transition zone between the winter and summer rainfall areas, and has an average annual rainfall of 700 mm. The climate is mild with the orchards sited about 5 km from the Indian Ocean. The 30-year average maximum and minimum daily temperatures for Port Elizabeth during summer are 24°C and 21°C and 21°C and 11°C during winter (South African Weather Services).

The orchards are irrigated by drip irrigation with irrigation needs determined by tensiometer readings. The soils are sandy loams underlain with thixotropic sub layers. To overcome the problem of these thixotrophic layers the plants were planted on raised beds of about 30 to 40 cm high and one meter wide. Cultivation practices followed in the trial plot such as pest and disease control, weed control and fertilising, were the same as those for the commercial orchards. By-pass shoots developing from axillary positions below the developing inflorescences were removed as part of the orchard cultivation operations. Plants were grown in rows running east to west on a southern slope 3 meters apart with 1 meter between plants in the row giving a stand of about 3,300 plants per hectare.

Trial layout, treatments and data recorded:

Plants were pruned either on the 18th of November 1999 or the 29th of February 2000. Bearers left after the heading cut were as follows: ½ a growth flush (±8 cm which equated to 6 to 7 leaves on a bearer), one full growth flush (±18 cm), two growth flushes (±32 cm) or three growth flushes (±48 cm). Between 27 and 32 bearers were left per plant. On average this left 1.6 bearers per centimetre of the root collar circumference. Of these bearers, two were selected per plant to evaluate the results of the treatments. These bearers were tagged and the following parameters were measured at the time of heading:

1. diameter of each plant's root collar,
2. diameter of the two tagged bearers at the base of the bearer,
3. the number of leaves on each of the two bearers and,
4. the length of the two tagged bearers.

The numbers of days to first bud break as well as the number of buds sprouting per bearer were recorded. Stems were harvested with a heading cut flush with the bearer, leaving no stub. The non-flowering shoots were left on the bearer to flower in the following season. All flowering stems were harvested at the soft bud stage and taken to the pack house and sorted to the different length categories.

Single plants were used per treatment, replicated five times in a randomised complete block design. Data were analysed using the SAS General Linear Means (GLM) procedure (SAS, 2002).

Results

About two months subsequent to the November pruning treatment it was noticed that the plants pruned to ½-flush bearers displayed stress symptoms with leaves showing autumn colours – the leaves on the plant became yellow and orange with the leave tips eventually dying and one plant dying after four months. All the plants pruned to ½-flush bearers and two of the plants pruned to one-flush bearers in February 2000, died by May 2000. An increase in bearer length shortened the response time for the axillary buds to start growing and more buds sprouted (Table 1). When the dead plants were omitted from the dataset a significant positive correlation existed between bearer diameter and number of buds sprouting per bearer but not with number of flowers harvested (Table 2). As expected, there was a linear relationship between the length of the bearer and the number of leaves per bearer (R^2 = 0.96), with the result that significant negative correlations existed between both these two parameters and number of days to buds sprouting on bearers and average stem length of flowers harvested and a significant positive correlation with the number of buds breaking after the pruning treatment, the number of flowers harvested (Table 2).

The cropping pattern of 'Pink Ice' revealed that irrespective of month of pruning or pruning severity, few flowers were picked during December or January either in the first cropping season or in the return bloom. The bulk of the crop was picked from February to July for the first crop and from February to May for the return bloom (Table 3). For the duration of the trail less than 5 percent of the flowers were picked from August to end January. Flower yield was higher for plants pruned in November and the yield increased with increase in bearer length (Table 4).

Mean stem length was affected by month of pruning for the shorter bearers and a significant decrease in length with increase in bearer length (Table 5) with the result that the proportion of flowers with long stems decreasing with increasing length of the bearers. This result was not as visible during the first cropping season as during the second cropping season (Table 6). The relationship between length of flowering shoots and month of harvest for all treatments is presented in Figure 1. 'Pink Ice' normally produces by-pass shoots during the period of flower development from the time of flower initiation to anthesis. These shoots are normally removed in the orchard to prevent unsightly marks on the flower stems should they be removed after the harvesting operation. The effect of the different pruning regimes on by-pass characteristics is summarised in Table 7.

Discussion

Gerber *et al*. (2001a) revealed that flower initiation in a number of *Protea* cultivars occurred during the early phases of a shoot growth flush and by completion of flush extension, differentiation of an inflorescence had advanced to the stage where all the involucral leaves had differentiated. In all the cultivars studied it appears that the spring flush that develops terminally on an over-wintering shoot is the preferred flush for flower initiation to occur. In the cultivar 'Carnival', flower initiation was essentially limited to this spring flush (Gerber *et al*., 2001a) with the result that anthesis occurred from February to May. In the case of 'Pink Ice', although flower initiation occurred predominantly on a spring flush, flower initiation could also occur on an autumn flush provided the shoots were in excess of 70 cm by May (Paper 1). When flower initiation occurred on an autumn flush, anthesis was achieved during December and January, whereas anthesis occurred from February to May for flowers borne on a spring flush.

On the other hand, 'Sylvia' could initiate flowers on any flush but the spring flush was still the preferred flush for flower initiation (Gerber *et al*., 2001b).

Failure to produce flowers that were harvest mature during December and January for both the first crop and the return bloom when plants were pruned in November is in agreement with the results in Paper 1. Shoots failed to acquire the Characteristics that were needed to effect flower initiation on an autumn flush. The longer bearers had more buds sprouting, resulting in more competition for resources amongst the developing shoots, and the shorter bearers took on average 1½ month to have buds sprouting from axillary positions on the bearers with plants also depleted of resources as indicated by the stress signs showing in the leaves. In contrast to results in Paper 1, pruning in February did lead to flowers in January of the return bloom although it were insignificant numbers (Table 3). Growth of plants after pruning in February to one-flush bearers for this trial, was considerably poorer than that of plants pruned in February as described in Paper 1. The combined yield per plant for the first and return bloom was double in the latter case in spite of plants being approximately one year younger. The poorer shoot growth accounts for the failure to initiate flowers on an autumn flush. This can be a result of the higher number of bearers left in this trial, with an average 31 bearers per plant and 1.6 bearers per cm of stem circumference at the root collar vs. the 11 bearers per plant and 0.8 bearers per cm of stem circumference for the plants described in Paper 1.

The extension of the cropping season into June and July and in particular when long bearers were left on the plant, is possibly related to the increased number of shoots that developed per bearer. Due to the acrotonic branching habit, shoots that developed lower down on a bearer are correlatively inhibited by the more distally situated shoots (Bangerth, 1989). De Swardt (1989), Greenfield *et al*. (1994) and Gerber *et al*. (1995) showed that flowers borne on poor quality shoots (short and thin), took longer to complete their development, compared to flowers borne on the same flush but on long, thick shoots. In this trial it was also found that there was a strong positive correlation between the diameter as well as the length of the bearer and the number of buds sprouting per bearer. Furthermore, apart from the limited photosynthetic source due to the smaller leaf area, shorter shoots are exposed to lower light intensities of poorer light quality. Shoots that are subordinated by distally situated shoots on the same bearer are not only shorter but also thinner. We therefore conclude that the June and July harvested flowers were borne on a spring flush of subordinated over-wintering shoots and were not initiated on a flush that followed the spring flush.

The economic impact of the treatments is summarised in Table 6. The effect of the longer bearers can be seen in more flowers harvested, not only per plant but also per bearer with the November treatment also outperforming the February treatment due to the longer period that was available for stems to increase in length before the cut-off period in May (Paper 1) was reached. The result of these higher numbers of stems affected the average stem length and thus also the average price realised per stem. The lower average price per stem was compensated for by the higher number of stems harvested over the two cropping seasons. The effect of the higher prices received for longer stems resulted in less variation in the income per plant than in the number of flowers harvested per plant.

The difference in the lengths of stems harvested over the two seasons is visible in Figure 1. The first harvest season differed from the second season as the lengths increased again towards the end of the first season. This differs from the results of the second season, which reacted similarly to the three seasons of harvesting reported in Paper 1 where the average length of harvested stems decreased towards the end of the harvesting season. The reason for the increase towards the end of the season in this first season is that the plants with the longer bearers were the first to produce a harvest with the stems shorter due to more flowering stems produced per plant and bearer. Later in the season the stems produced on these plants were longer due to another vegetative flush being added to the stems and the plants with the shorter bearers also produced flowers later in the harvesting period, which were generally longer due to fewer flowering stems produced per plant and bearer.

With the elimination of apical dominance this cultivar normally produces by-pass shoots during flower development from the time of flower initiation to anthesis. The longer bearers resulted in more by-pass shoots produced per plant but this was caused by the higher number of stems produced per plant except for the February treatment with one-flush bearers. The shorter bearers on average resulted in more by-pass shoots per flowering stem. The February treatment also resulted in significantly higher numbers of by-pass shoots per stem (Table 9).

The flowering period of stems resulting from the treatments in this trial was later than normal during the first cropping season for the November treated plants and more so for the February treated plants (Table 3 and Table 8). During the second cropping season the harvesting period was in line with the normally expected period of February to May for ‘Pink Ice’.

To conclude, more flowers were borne on long bearers than short bearers, however the increased yield was borne on shorter shoots that reached harvest maturity during June and July when demand for flowers on the European markets is low. As such the principle of pruning with longer bearers to produce more stems does not give a better return than normal pruning during June when the bearers are cut at the first intercalation as described in Paper 1.

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Table 1. Effect of time of pruning and pruning severity on the average time in days for buds to start sprouting after the treatment and average number of buds developing per bearer (dead plants omitted from dataset).

Month pruned		Days to bud break		Buds developing	
		Average	STD	Average	STD
November 1999	½ Flush (1)	43.4^{b}	7.42	4.0^{c}	1.82
	1 Flush (2)	21.2^{c}	1.69	7.8^{ab}	2.44
	2 Flush (3)	16.3^{d}	2.87	10.4^{a}	3.13
	3 Flush (4)	12.9^{d}	2.76	9.7^{a}	4.42
February 2000	½ Flush (5)	[y]		0.0^{d}	0.00
	1 Flush (6)	49.3^{a}	9.09	5.8^{bc}	5.79
	2 Flush (7)	22.0^{c}	5.33	10.5^{a}	3.50
	3 Flush (8)	22.1^{c}	5.34	8.3^{ab}	2.54

(Means within month and columns followed by the same letter are not significantly different at P = 0.05 LSD test)

[y] Plant deaths following treatment precluded data analysis

Table 2. Pearson correlation coefficients for intrinsic values of variables measured on the plants at time of treatment and results of the treatments. The lower line in each instance is the probability that |r| under H_0: $\rho = 0$ (dead plants omitted from dataset).

		Bearer diameter	Bearer Length
Buds breaking	R^2	0.3852	0.3912
	Significance level	0.0295	0.0268
Days to bud break	R^2		-0.6234
	Significance level	n.s.	0.0001
Stem length	R^2		-0.5864
	Significance level	n.s.	0.0004
Flowers harvested	R^2		0.5952
	Significance level	n.s.	0.0003

Table 3. Cropping pattern of 'Pink Ice' as affected by date of pruning and bearer length. (N = 5)

Prune date	Bearer length	Flower stems harvested per plant																
		2001												2002				
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
November 1999	½				2	3	1							1	3	7	2	
	1			3	5	10	5	1							4	9	4	
	2			7	6	15	5	1	1						5	10	7	1
	3			10	10	16	5	3							4	10	5	2
February 2000	½																	
	1							5	1		1	1		1	4	9		
	2					6	2	2	1		1	2			8	10	2	1
	3				1	13	6	6	1		1			1	8	10	1	1

Shaded area denotes preferred marketing period

Table 4. Effect of month of pruning and bearer length on the number of flowering shoots per plant for two cropping seasons as well as the total period in which the trial was harvested (N = 5 in each treatment)

Month of pruning	Bearer Length	Flowering shoots harvested per plant			
		Feb-Jul 2001	Feb-May 2002	Total	Total Feb '01-May '02
November 1999	½ Flush	4.8	12.6	17.4	19.4[de]
	1 Flush	18.6	17.4	36.0	43.6[bc]
	2 Flush	28.2	23.0	51.2	59.2[ab]
	3 Flush	36.0	21.0	57.0	65.0[a]
February 2000	½ Flush	0.0	0.0	0.0	0.0 [f]
	1 Flush	0	12.8	12.8	17.0[e]
	2 Flush	6.6	21.0	27.6	36.0[cd]
	3 Flush	13.2	20.0	33.2	48.0[bc]

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

Table 5. Effect of month of pruning and pruning intensity on the mean length of flowering shoots per plant for the 2001 and 2002 cropping seasons and the average stem length harvested over the two cropping seasons.

Month of pruning	Bearer Length	Mean stem length (cm)		
		2001	2002	Average
November 1999	½ Flush	56.7	71.0	66.5[b]
	1 Flush	61.3	69.4	65.8[c]
	2 Flush	56.4	62.8	58.4[c]
	3 Flush	54.6	59.1	56.2[c]
February 2000	½ Flush			
	1 Flush	56.7	78.4	75.7[a]
	2 Flush	57.0	79.1	66.4[b]
	3 Flush	53.9	61.3	57.4[c]

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

Table 6. Economic value of pruning time and intensity (all results for two cropping seasons and N = 5)

Month of pruning	Bearer Length	Income/plant	Flowers/plant	Flowers/bearer	Average Price/stem
November 1999	½ Flush	R 45.25[b]	19.4[de]	0.6	R 2.33
	1 Flush	R 97.25[a]	43.6[bc]	1.4	R 2.23
	2 Flush	R 118.18[a]	59.2[ab]	1.9	R 2.00
	3 Flush	R 121.99[a]	65.0 [a]	2.2	R 1.89
February 2000	½ Flush	R 0.00[c]	0.0 [f]	0.0	R 0.00
	1 Flush	R 47.10[b]	17.0 [e]	0.6	R 2.77
	2 Flush	R 87.81[a]	36.0[cd]	1.2	R 2.44
	3 Flush	R 103.59[a]	48.0[bc]	1.6	R 2.16

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

Table 7. Number of by-pass shoots removed per plant and per stem harvested for all treatments,

Month of pruning	Bearer Length	By-pass shoots/plant	By-pass shoots/flower
November 1999	½ Flush	31.5 [b]	1.4 [bc]
	1 Flush	49.4 [ab]	1.1 [bc]
	2 Flush	62.4 [ab]	1.1 [bc]
	3 Flush	67.6 [ab]	1.1 [c]
February 2000	½ Flush	-	-
	1 Flush	72.7 [a]	2.6 [a]
	2 Flush	67.6 [ab]	1.9 [ab]
	3 Flush	70.8 [a]	1.4 [bc]

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

Table 8. The peaks in flower production of this trial compared with the results from Paper 1 where the plants were pruned over a 12-month period.

		February treatment		November treatment	
		Bearers	Monthly	Bearers	Monthly
First season	First peak	Week 20	Week 20	Week 14	Week 10
	Second peak		Week 24	Week 20	
Second season	First peak	Week 10	Week 2	Week 9	Week 11
	Second peak		Week 8	Week 13	Week 16

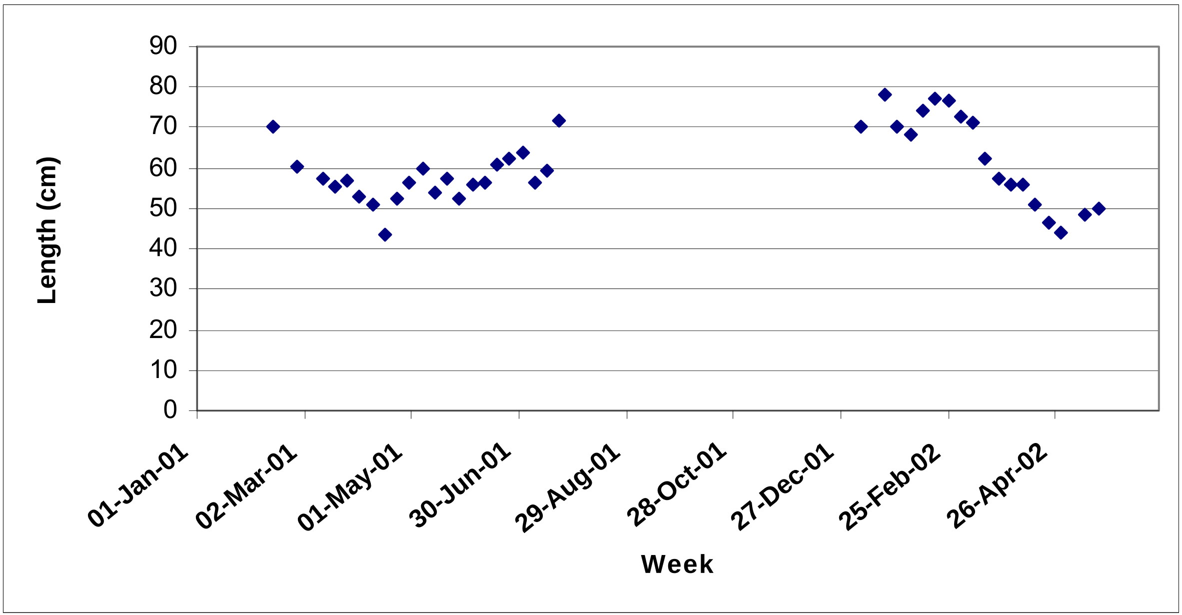

Figure 1. Relationship between time of harvest and stem length for *Protea* ‘Pink Ice’ (weekly averages for all stems harvested for all treatments)

Paper-3. Biennial Cropping of *Protea* 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.)

Abstract

***Protea* 'Pink Ice' plants were pruned at monthly intervals over the twelve-month period of January to December 1999. Single plants were used per treatment and treatments were repeated five times in a randomised complete block design. The effect of cropping this cultivar in a biennial system was tested in a commercial business with actual prices to test the validity of the finding of a related paper that the June treatment resulted in the highest number of harvestable stems in the 24 month period after pruning (37 stems per plant). The economic value of a plant in a commercial orchard is not only determined by the number of stems produced per annum but also by the length of these stems and the timing of production. It was found that the June treatment gave the best income (R109.80 per plant) and the phasing of production resulting from a June pruning in a biennial cropping system fitted this cultivar the best. The average number of stems produced in the desired length of more than 60 cm was also sufficient enough to warrant the harvesting of stems of shorter lengths by cutting these stems without leaving a bearer. Longer stems could be harvested by leaving a long bearer during the harvesting process, which could be undercut during the pruning operation in June following the harvesting operation from December to May. Orchards should be divided into two blocks with one in the 'on year' and one in the 'off year'.**

Introduction

The main purpose of producing cut flowers is to earn a satisfactory income and all methods and means are sought to increase this income potential. Normally the first effort is to increase the total number of flowers produced, but this has a limit due to the number of flowers that can be produced per plant or per area planted. Another method is to get the bulk of the crop in the longest possible stem length category as longer stems earn better prices. A third option is to target the seasons or times of the year when prices are naturally higher due to a positive ratio between demand and supply (i.e. the winter period in European markets when supply is down due to various constraints on local producers) or specific holiday seasons (Valentine's Day, Easter, All Saints, Christmas, etc.). As these crops are grown outdoors, where the climate is not controlled, it is difficult to aim for a specific day like Valentine's Day or Mother's Day as can be done with greenhouse produced crops such as roses or chrysanthemums. It has however been found that the flowering period of some protea cultivars could be shifted to more favourable marketing periods through the timing of the pruning operation.

Pruning of commercial protea orchards to follow a biennial production cycle with positive production results has successfully been established in, for example 'Carnival' (Hettasch *et al*., 1997), where the authors also posed the question whether 'Pink Ice' could be adapted to biennial cropping with an increase in productivity versus the normal practice of annual harvesting and pruning. The normal procedure is to harvest these plants by leaving a stub of about 10 to 15 cm of the flower stem on the bearer. When the harvesting season is finished, the plants are cleaned by the removal of thin or weak shoots, and the reduction of the remaining bearers to a number that is adequate for a plant of that specific age and size and the production potential of the orchard.

'Pink Ice' normally flowers from January to September in South Africa with peak production from February to August (SAPPEX, Undated). Figure 1 illustrates the number of 'Pink Ice' flowers exported from South Africa for the period July 2000 to June 2001 (SAPPEX, 2000) and the average price received for 'Pink Ice' on the commercial farm where this trial was laid out. It is clear that there is an opportunity to increase the number of stems produced in the period December and January with less than 10% of the annual production exported in these two months when average prices double those realised for the period February to June.

In this paper we report on the effect of the time of pruning on the economic return of 'Pink Ice' and propose that this cultivar can be cropped in a biennial system with better returns than cropping it annually.

Materials and Methods

Plant material and study site:

Three-year-old plants of 'Pink Ice' (*P. compacta* R. Br. x *P. susannae* Phill.) growing in a commercial plantation near Port Elizabeth (40 km to the east), Eastern Cape, South Africa (lat. 33°30'S: long. 24°55'E, altitude 240 m), were used in the trial. The area is in the transition zone between the winter and summer rainfall areas, and has an average annual rainfall of 700 mm. The climate is mild with the orchards sited about 5 km from the Indian Ocean. The 30-year average maximum and minimum daily temperatures for Port Elizabeth during summer is 24°C and 21°C and during winter 21°C and 11°C (South African Weather Services).

The orchards are irrigated by drip irrigation with irrigation needs determined by daily tensiometer readings. The soils are sandy loams underlain with thixotrophic sub layers. The plants were planted on raised beds of about 30 to 40 cm high by one meter wide to overcome the problems associated with these thixotrophic layers. Normal cultivation practices of the commercial orchards such as pest and disease control, weedings and fertilising, were followed in the trial plot. Plants were grown in rows, running north to south, 3 meters apart with 1 meter between plants in the row and received the normal practice of pruning to produce a crop and also following harvesting in the preceding year. The orchard had produced a harvest in the previous year and the shoots pruned in this trial were shoots that grew from axillary buds on bearers left after stems were harvested from January to May 1998.

Trial layout, treatments and data recorded:

The trial was laid out in two rows in the commercial orchard and plants randomly allocated to the pruning dates. Five plants were pruned about four weeks apart on the following dates in 1999: 14 January, 16 February, 16 March, 16 April, 19 May, 18 June, 19 July, 19 August, 17 September, 20 October, 18 November and 28 December. The stems were harvested when the flowers were in the soft-bud stage. The stems were taken to the pack house and sorted to the different length classes.

To ascertain whether it will be feasible to introduce a biennial cropping system for 'Pink Ice' the following was considered;

(a) Yield in the 24 month period after pruning,
(b) The proportion of flowers that are picked in December and January,
(c) The stem length distribution in a particular month.

Single plants were used per treatment, replicated five times in a randomised complete block design. Data was analysed using the SAS General Linear Means (GLM) procedure (SAS, 2002).

Results

Table 1A reveals that the highest yield is achieved for plants pruned in June or July whereas more stems were harvested during December and January when plants were pruned during February or March (Table 1B). The average price realised per stem can drop by more than 50% from January to February. In March the price will drop even further to about 40% of the January price (Table 2). This has a significant effect on the average price per stem for the different treatments (Table 3). The plants treated in June not only produced the most stems (although not significantly more than the plants treated in the months of April to September), but also the highest income per plant (although not significantly more than the plants treated in the months of February to August) (Table 4 and Figures 2 and 3).

Discussion.

Harvesting of a season's crop of 'Pink Ice' extended over a period of 6 months from December to May. Since only 4% of the crop was harvested outside these months (Paper 1), the stems harvested from June to November were therefore ignored in this paper. The time from pruning until the onset of cropping was at its shortest 14 months. This implies that it is not possible to produce a crop within one calendar year after pruning, irrespective of the month in which pruning was executed. Since harvesting of this cultivar can extend from as early as December and is concluded in May, pruning of plants should be done from June to August. The highest number of stems in a 2-year cycle was produced when plants were pruned in June or July (Table 4). When pruning was done in any of the months from January to May 1999, part of the crop would have been sacrificed had plants been repruned in January to May 2001. Fewer flowering stems were also harvested when pruning was done from August to September (not significant). The reason for the decrease in this case is that the length of the period from pruning in 1999 becomes shorter before the onset of the spring flush in 2000 the later the pruning was done. This resulted in fewer shoots acquiring the characteristics that permitted flower initiation on the spring flush of 2000.

More stems flowered in December and January when plants were pruned in June when compared to July. This had a positive impact on the prices realised per stem and the average stem length produced by the June treatment was also 83.7 cm for the period December 2000 to May 2001 vs. the 81.1 cm for July. Even though the June and July treatments produced the same number of stems for the period December 2000 to May 2001 (36.6 stems per plant), the June treatment produced 25% of the crop in the period December 2000 and January 2001 vs. the 18% for the July treatment. This resulted in the June treatment earning 40% of the income per plant (R43.80 of a total of R109.80) in the December and January period vs. the 31% for the July treatment (R31.40 of a total of R102.20) (Table 4). The total income realised per plant pruned in June 1999 should result in a yield of about R300, 000 per hectare every second year in a commercial orchard planted at 3,000 plants per hectare and an average die-back of 2% per year (as was the case in this orchard). It is thus concluded that for biennial cropping 'Pink Ice' plants should be pruned in June.

However, since pruning of shoots took place when flowers were harvested from December to May, shoot growth that occurred on the bearer after flowers were harvested will result in poorly synchronised shoot growth if the remainder of the shoots (non-flowering shoots) are pruned in June. Shoots sprouting on bearers cut in January were on average already 28 cm at the end of May (137 days subsequent to the treatment) (See Paper 1). Harvesting of the flowers should therefore be done in such a way that a long bearer is left on the plant. The bearers can then be re-cut in June when non-flowering shoots are also pruned to ensure proper synchronisation of shoot growth.

To establish the effect of this on maximising the stems harvested in the preferred stem length classes (longer than 60 cm), the percentage of stems shorter than 60cm were determined per treatment. Only the January and October treatments produced less than 90% of the crop in the category longer than 60 cm (Table 5 and Figure 4.) The June treatment had on average only 4% of the stems harvested in the categories shorter than 60 cm. This indicates that the stems in the longer categories can be harvested as suggested above and the shorter stems (less than 60 cm in length) can be harvested with a thinning cut, flush with the bearer. This practice would still leave a sufficient number of bearers to select from for the ensuing crop.

The next question to consider is the yield per plant when shoot growth is synchronised by pruning and a crop is only realised every second year, as compared to a crop every year but from non-synchronised shoot growth. Plants pruned in June or July 1999 yielded 36 flowering stems per plant. Growers' experiences with 'Pink Ice' reveal that annual yields per plant vary from 15 to 20 flowers (Hettasch, Pers. Comm.). The yield from a biennial crop after synchronisation of shoot growth is comparable or better than the combined yield of two consecutive crops from plants of which shoot growth was not synchronised. Gerber (1994) reported similar results for the cultivar 'Carnival' where a biennial yield of more than 50 flowers per plant was achieved after shoot growth synchronisation. This yield was also comparable or higher than the combined yield of two consecutive years from plants of which the shoot growth was not synchronised. Barth *et al*. (1996) found in a trial with 'Pink Ice' at three different locations in South Australia that 'Pink Ice' can produce between 39 stems per plant per year on infertile sites to 63 stems per plant on fertile sites. These values were achieved for 5 to 7 year old plants that were selected for their vigour vs. the plants in this trial that were 3 years old producing their second commercial harvest although no economic value was attached to the results. The plants selected for this trial came from a row in the commercial orchard without selecting plants for vigour.

When the financial impact of the pruning date is taken into consideration, June is the most appropriate time to prune 'Pink Ice' as it produced a crop worth R109.80 per plant at an age of five years. The pruning operations in the months prior to June (January to May) resulted in fewer stems than the treatments after June (July to December), but the average income per plant was more as these stems were longer and were also harvested earlier, which equated to better average prices, which is evident from Table 4. To implement the system of biennial cropping, an orchard should be divided into two blocks with one block in the 'on year' i.e. it is producing flowers and another block in the 'off year' with the plants producing vegetative shoots for harvesting in the following year. This can be established by planting an orchard in two consecutive years or an existing orchard can be divided into two blocks and all the vegetative shoots of the first preceding harvest and regenerative shoots of the following harvest can be pruned back to bearers in June. To aid this process, the harvest should be done in such a manner that the bearers left after the harvest should be of sufficient length and number to be undercut in June as indicated above.

In conclusion, biennial cropping of 'Pink Ice' by synchronising shoot growth through pruning plants in June gave high yields with more flowers harvested during the high price period of December and January and with longer stems than annual cropping from plants from non-synchronised shoot growth resulting in a higher yield per plant.

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Table 1. Monthly cumulative yield (A) and yield per month (B) for 'Pink Ice' in relation to the number of months following pruning in 1999 (Total stems harvested from five plants per treatment)

A	Months following pruning in 1999										
Month of pruning in1999	14	15	16	17	18	19	20	21	22	23	**24**
January		46	76	86	92	92	92	92	93	93	**105**
February	2	30	30	45	45	48	49	50	50	71	**121**
March					2	3	4	4	8	73	**113**
April								4	59	95	**148**
May							3	42	97	150	**164**
June							46	88	158	175	**183**
July						33	75	141	169	183	**184**
August				1	23	62	143	169	174	174	**174**
September				2	21	107	126	139	140	141	**141**
October			6	21	80	96	100	101	104	104	**107**
November*		3	9	56	72	79	83	86	86	87	**87**
December	6	6	16	53	77	81	98	98	100	101	**101**

B	Months following pruning in 1999											
Month of pruning in 1999	14	15	16	17	18	19	20	21	22	23	24	**Z**	**X**
January		46	30	10	6				1		**12**	**12^{ef}**	86^{bc}
February	2	28		15		3	1	1		**21**	**50**	**71^{a}**	30^{e}
March					2	1	1		**4**	**65**	40	**69^{a}**	40^{de}
April								**4**	**55**	36	53	**59^{ab}**	89^{bc}
May							**3**	**39**	55	53	14	**42^{bcd}**	122^{ab}
June							**46**	42	70	17	8	**46^{bc}**	137^{a}
July						**33**	42	66	28	14	1	**33^{cde}**	150^{a}
August				**1**	**22**	39	81	26	5	5	1	**23^{def}**	151^{a}
September				**2**	19	86	19	13	1	1		**2^{f}**	137^{a}
October			**6**	15	59	16	4	1	3		3	**6^{f}**	94^{bc}
November*		**3**	6	47	16	7	4	3		1		**3^{f}**	76^{bc}
December	**6**		10	37	24	4	17		2	1		**6^{f}**	71^{cd}

Z; Harvested December to January X; Harvested February to May

* November has one missing value

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

Table 2. Average prices realised per month for the period January to May 2001

	Average price per stem					
	90	**80**	**70**	**60**	**50**	**40**
January 2001	R 4.80	R 4.60	R 4.52	R 4.00	R 3.60	R 3.20
February 2001	R 3.43	R 2.75	R 2.45	R 1.93	R 1.84	R 1.61
March 2001	R 2.00	R 2.00	R 1.84	R 1.69	R 1.50	R 1.30
April 2001	R 2.26	R 2.26	R 2.26	R 2.01	R 1.53	R 1.37
May 2001	R 2.38	R 2.38	R 2.38	R 2.31	R 1.88	R 1.43
	Prices per stem as % of maximum price					
	90	**80**	**70**	**60**	**50**	**40**
January 2001	100%	96%	94%	83%	75%	67%
February 2001	100%	80%	71%	56%	54%	47%
March 2001	100%	100%	92%	85%	75%	65%
April 2001	100%	100%	100%	89%	68%	61%
May 2001	100%	100%	100%	97%	79%	60%
	Prices per stem as % of January prices					
	90	**80**	**70**	**60**	**50**	**40**
January 2001	100%	100%	100%	100%	100%	100%
February 2001	71%	60%	54%	48%	51%	50%
March 2001	42%	43%	41%	42%	42%	41%
April 2001	47%	49%	50%	50%	43%	43%
May 2001	50%	52%	53%	58%	52%	45%

Table 3. Distribution of average prices per stem harvested per treatment during the period December 2000 to May 2001.

	Harvesting month					
Treatment	**Dec 2000**	**Jan 2001**	**Feb 2001**	**Mar 2001**	**Apr 2001**	**May 2001**
January	R 4.83	R 4.76	R 3.12	R 1.88	R 2.00	R 1.50
February	R 4.81	R 4.76	R 3.29	R 1.88	R 1.75	R 2.25
March	R 4.75	R 4.80	R 3.33	R 1.85	R 2.20	R 2.40
April	R 4.75	R 4.80	R 3.42	R 1.91	R 2.08	R 2.00
May	R 4.67	R 4.77	R 3.35	R 1.91	R 1.86	R 2.20
June		R 4.76	R 3.38	R 1.93	R 2.12	R 2.13
July		R 4.76	R 3.24	R 1.91	R 2.14	R 2.21
August	R 5.00	R 4.77	R 3.31	R 1.89	R 2.12	R 2.20
September		R 4.50	R 3.16	R 1.86	R 2.16	R 2.08
October		R 4.33	R 3.20	R 1.86	R 2.06	R 2.25
November		R 4.75	R 3.00	R 1.82	R 2.21	R 2.15
December		R 4.67		R 1.80	R 1.78	R 2.25
Average	**R 4.80**	**R 4.76**	**R 3.29**	**R 1.88**	**R 2.04**	**R 2.18**

Table 4. Commercial harvest and income for all treatments for the two periods of harvesting of 'Pink Ice'. Harvest period A is the preferred period of December and January when average prices are high and Harvest period B is for the months of February to May when average prices are lower (N = 5).

	Commercial harvest						Total	
Treatment	Harvest period A	Yield	Income	Harvest period B	Yield	Income	Yield	Income
January	Dec-00	2.4ef	R 11.52ef	Mar 00 - May 00	17.2bc	R 51.43abc	19.6cd	R 62.95bcd
February	Dec 00 - Jan 01	14.2a	R 67.80a	Mar 00 - May 00	6.0e	R 15.71e	20.2cd	R 83.51abc
March	Dec 00 - Jan 01	13.8a	R 66.20a	Feb-01	8.0de	R 25.94de	21.8bcd	R 92.14ab
April	Dec 00 - Jan 01	11.8ab	R 56.56ab	Feb 01 - Mar 01	17.8bc	R 44.84bcd	29.6ab	R 101.40a
May	Dec 00 - Jan 01	8.4bc	R 39.86bcd	Feb 01 - Apr 01	24.4ab	R 61.98ab	32.8a	R 101.84a
June	Dec 00 - Jan 01	9.2bc	R 43.88bc	Feb 01 - May 01	27.4a	R 65.99a	36.6a	R 109.87a
July	Dec 00 - Jan 01	6.6cde	R 31.44cde	Feb 01 - May 01	30.0a	R 69.98a	36.6a	R 101.42a
August	Dec 00 - Jan 01	4.6def	R 21.94def	Feb 01 - May 01	30.2a	R 69.54a	34.8a	R 91.48ab
September	Dec 00 - Jan 01	0.4f	R 1.86f	Feb 01 - May 01	27.4a	R 57.12abc	27.8abc	R 58.98cd
October	Dec 00 - Jan 01	1.2f	R 5.29f	Feb 01 - May 01	18.8bc	R 39.75cd	20.0cd	R 45.04d
November*	Dec 00 - Jan 01	0.8f	R 3.55f	Feb 01 - May 01	19.0bc	R 37.13cd	19.8cd	R 40.68d
December	Dec 00 - Jan 01	1.2f	R 5.70f	Feb 01 - May 01	14.2cd	R 30.68cde	15.4d	R 36.38d
Lin.^{z}		**	**		*	n.s.	**	**
Quad.^{z}		**	**		**	**	**	**
Cub.^{z}		**	**		**	**	**	**

* November has one missing value

(Means within columns followed by the same letter are not significantly different at P = 0.05 LSD test)

^{z} *, ** significant at P=0.05 and P=0.01 respectively and n.s. is not significant according to the F-test

Table 5. Number and percentage stems per plant in the stem length categories 30 to 50cm and 60cm and longer.

	Average number of stems and percentage				
Treatment	**30 – 50cm**	**%**	**60cm +**	**%**	**Total**
January	2.6	13%	17.0	87%	19.6
February	0.8	4%	19.4	96%	20.2
March	0.0	0%	21.8	100%	21.8
April	0.6	2%	29.0	98%	29.6
May	1.8	5%	31.0	95%	32.8
June	1.4	4%	35.2	96%	36.6
July	1.4	4%	35.2	96%	36.6
August	2.4	7%	32.4	93%	34.8
September	2.6	9%	25.2	91%	27.8
October	2.2	11%	17.8	89%	20.0
November	2.2	8%	26.0	92%	28.2
December	0.8	5%	14.6	95%	15.4

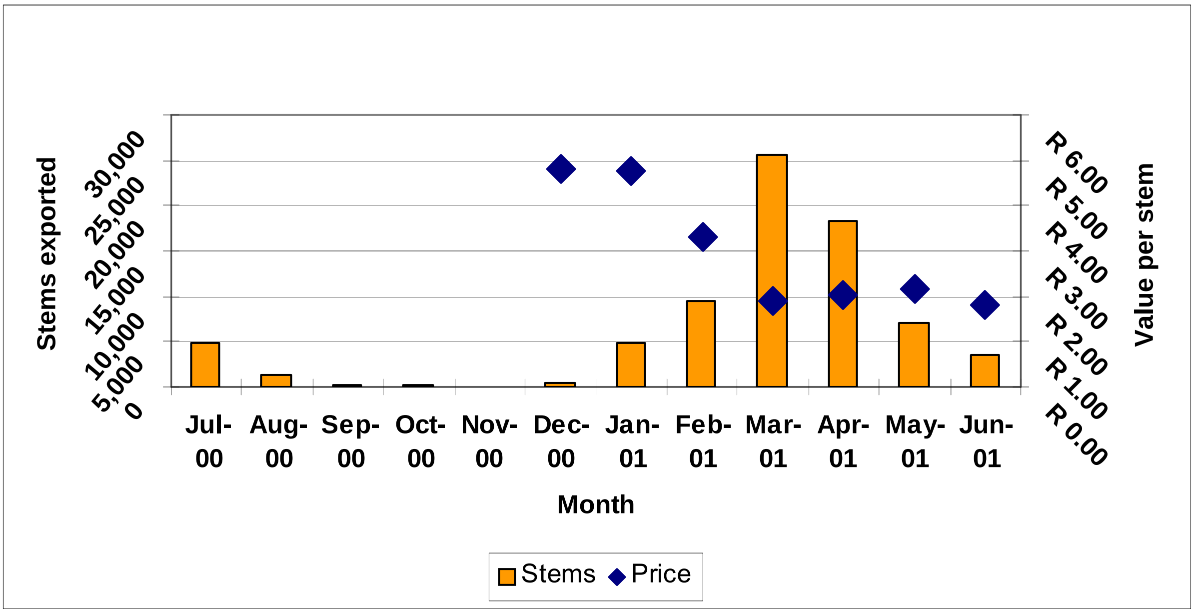

Figure 1. South African export figures for ‘Pink Ice’ from July 2000 to June 2001 (SAPPEX, 2000) and actual average prices achieved in the commercial orchards on the farm from December 2000 to June 2001.

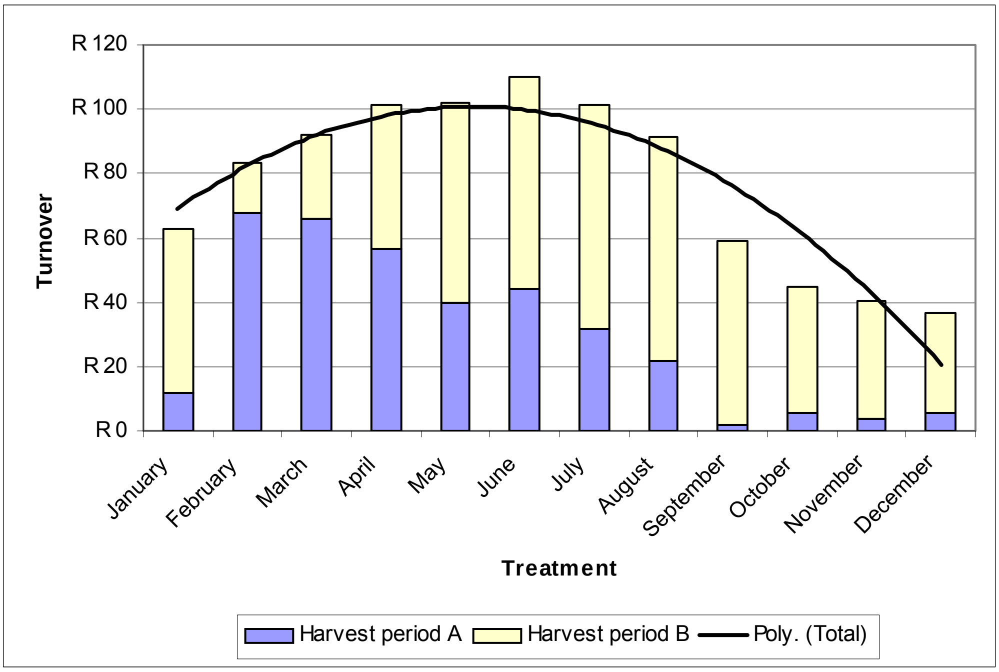

Figure 2. The average turnover per plant in the period March 2000 to May 2001. Treatment is the month of pruning and Harvest period A the income received from December 2000 to January 2001 and Harvest period B the income for the rest of the period.

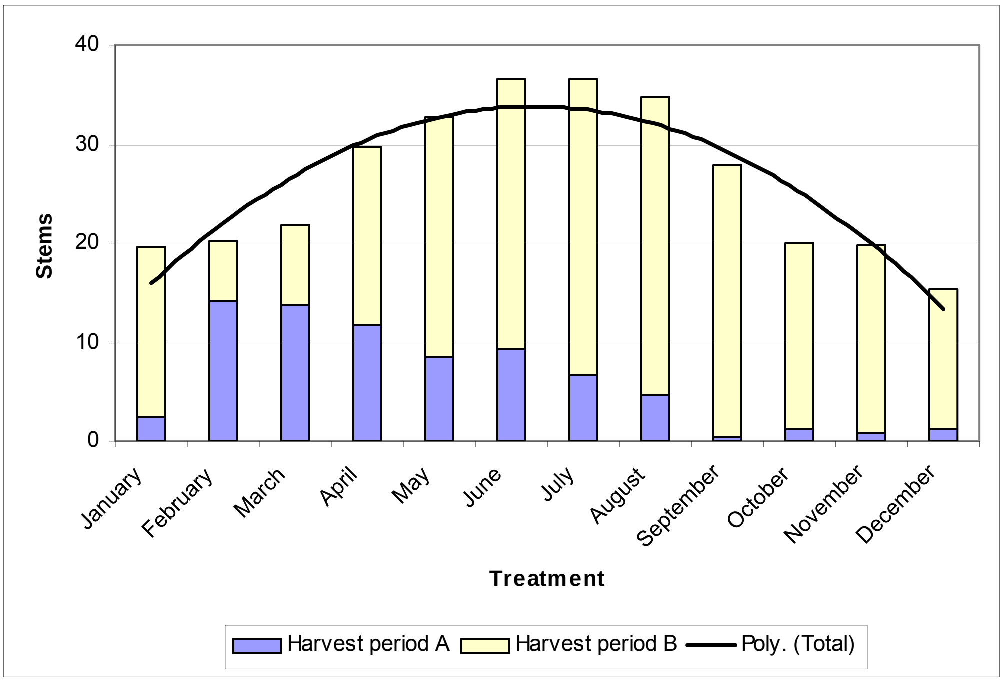

Figure 3. Average number of stems harvest per plant per treatment from March 2000 to May 2001. Treatment is the month of pruning and Harvest period A the stems harvested from December 2000 to January 2001 and Harvest period B the stems for the rest of the months.

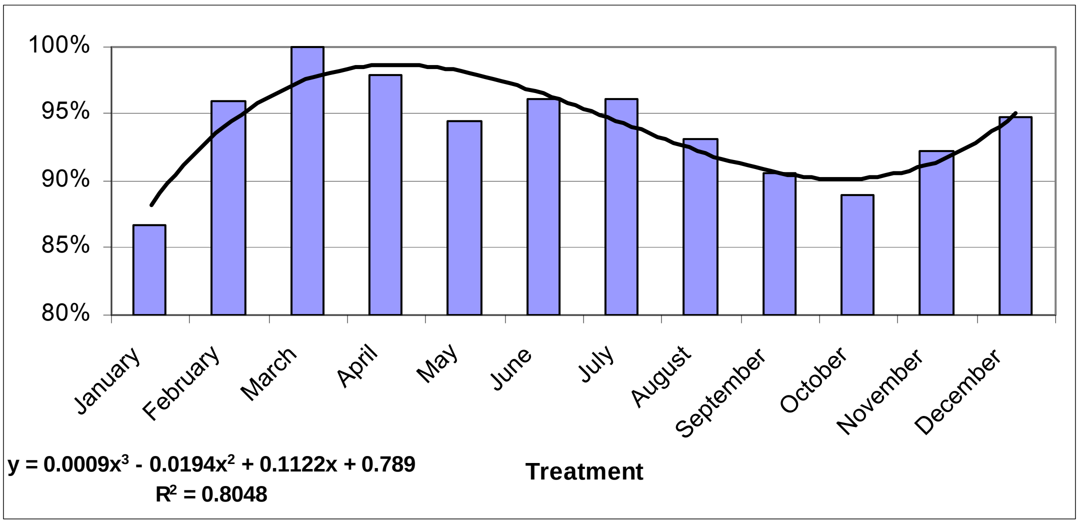

Figure 4. Percentage of the crop harvested in the stem length category 60cm and longer in the period December 2000 to May 2001 following pruning from January to December 1999.

General Conclusions

It was established that the length of shoots in May plays a determining role in the reality of the shoot producing a flower in the following season or not. Although the work done in these trials could not succeed in shifting the flowering period earlier than December, it did point out that June was the most appropriate time to prune ‘Pink Ice’ and that this cultivar can be produced more cost-effectively in a biennial system than in an annual system. The biennial system with pruning in June was economically superior to any of the treatments pruned in other months, or the present practice of pruning during the harvesting process with a clean-up pruning operation in May after the harvesting period. This would necessitate the grower to establish two blocks in the orchards with one section in the ‘off year’ producing vegetative shoots and the other section in the ‘on year’ producing the flowers on the vegetative shoots of the previous year’s growth.

With the increase in bearer length the plants are able to produce more harvestable stems, but with shorter stem lengths and lower average income per stem although the return per plant was the highest with longer bearers. The peak flowering period for both pruning times of this trial was later than normal. The practicalities of pruning to long bearers preclude this practice from being a viable alternative in commercial orchards.